THE STATE AND EFFICIENCY OF A HUMAN BEING DURING PROLONGED CONFINEMENT IN A SPACECRAFT SIMULATOR

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One of the factors incident to prolonged confinement of a human being in a spacecraft is the limitation of his mobility (hypodynamic). It has been shown that prolonged hypodynamia may have a deleterious effect on the functional state of the organism and efficiency of a human being [6, 7, 9, 14—16].

The problem of the present research is to study the overall state and efficiency of man during prolonged (12-day) confinement in a spacecraft simulator in the absence of special mean to counteract the negative effects of hypodynamic.

METHOD

The test subject remained for 12 days in his space suit half-lying in the seat of the spacecraft simulator. The model was hermetically and acoustically sealed off from the surroundings. The microclimate in the cabin was maintained by an autonomous system in conformity with a prescribed program. The air temperature within the cabin fluctuated between 12-24°, the humidity from 45 to 65%, the oxygen content from 18 to 20%, and the carbon dioxide content did not exceed 1%. The microclimate in the pressure suit was regulated by the test subject by changing the volume of circulating air. The test subject was fed and supplied with water by using one of the various types of space rations. A special sanitation device was used to take care of the natural functions. /160

For the purpose of better imitation of flight conditions, illustrations of the celestial canopy and also images of the earth and moon were set up in front of the space-cabin illuminators. According to the experimental program, at certain fixed periods the test subject oriented the craft, made a radio report, performed various test functions and made records in the spacecraft log.

The overall state and physiological reactions of the test subject were continuously monitored over a television hookup by observing the pulse rate, the respiration rate, the electrocardiogram pattern, encephalograms and other physiological indicators. A block diagram of the setup and equipment designed to monitor the state of the test subject is given in Fig. 1.

To accomplish the research goal a large complex of psychological methods was used in the experiment, and with these methods we studied such aspects as the operational reliability of the tester in controlling a spacecraft manual orientation system, the stability of complex sensomotor habits, and mental and physical capabilities. The transmission capacity of the visual analyzer was studied by the method described by A. A. Genkin, V. I. Medvedev, and M. P. Shek [2]. Tables

were compiled from Landolt rings of equally probably directions. The test subject was to look over all signs and pick out prescribed useful signals. The criteria for work evaluation were the time expended in examining tables, and also the number of recognized and transmitted useful signals. The bioelectrical activity of the muscles during tests on the coordinograph and dynamograph were determined from the wrist flexors. The galvanic skin reaction was investigated by Tarkhanou's method. The bioelectric activity of the cerebral cortex was recorded with an electroencephalograph using a frequency analyzer and frequency integrators, applied to the forehead and occiput (left side).

Before and after the experiment the test subject was given a general clinical examination, applying the orthostatic test, and was examined while applying a functional load on a treadmill and in a centrifuge. The effect of gravitational loads during rotation of the centrifuge reached 10.5 t, in a line through the chest and back. In the centrifuge experiment we studied the response reactions of the test subject to light signals and also the parameters of the medical check (EKG, KGR, the respiration rate, etc.).

EXPERIMENTAL RESULTS AND DISCUSSION

The overall state and health of the test subject during the entire experiment was satisfactory. All instructions transmitted from the monitor central were carried out in accordance with the program. Evaluation of the environmental situation and responses to questions were correct. /162

In the course of the experiment the test subject development symptoms of general asthenia, accompanied by the appearances of irritability, fatigue, deteriorating appetite, a drop in the functional activity of a number of physiological systems of the organism, and some deterioration of the quality with which functional tests and special tasks included in the experimental program were performed.

The data on control of a manual spacecraft orientation system indicate that the operational reliability of a test subject underwent a number of changes. In the first three days, a tendency was noted to increase the time spent in spacecraft orientation, as compared with the original state. The work motions in control were someshat slowed down. Following the period the time spent in orientation speeded up and did not differ appreciably from the original.

The precision with which the orientation tasks were carried out also decreased on several days of the experiment (7th and 11th).

In studying the capability of the test subject to transmit information by means of a teletype instrument it was found that the operational reliability also decreased toward the end of the experiment. The time spent to transmit a symbol increased from 0.7 to 0.8 sec. The number of transmitted symbols decreased from 1.3 to 1.2 per sec. The overall capacity insofar as time spent in transmitting standard information is concerned decreased by 10%. In order to establish the initial indexes for working habits, two exercizes were required on the second day after the experiment. Each exercise included the transmission of standard tests consisting of 150 printed symbols.

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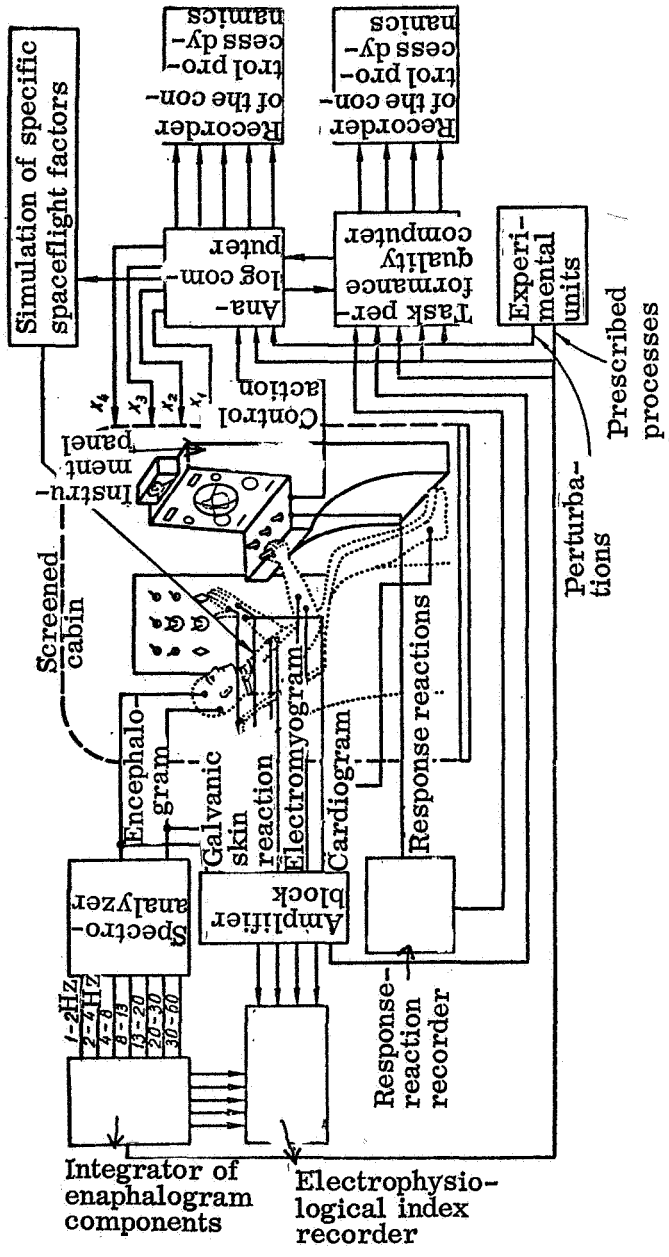

Figure 1. Block Diagram of the Recording of Certain Indicators of the State and Efficiency of the Test Subject During the Experiment.

Investigations by means of correctional tables showed that the transmission capacity of a visual analyzer in carrying out a test with Landolt rings decreased toward the end of the experiment from 1.7 to 1.3-1.5 bits/sec. Losses of useful information by the visual analyzer increased by 8-10 signals, and the time spent in recognizing useful signals increased by 30 to 60 sec. Deserving of attention is the fact that a decrease in the contrast sensitivity of the eyes to red and green light by 35 and 45%, resp., was noted toward the end of the experiment (L. N. Meier).

In analyzing the electroencephalogram records (EEG) it was found that a state of stagnant exaltation of the α-rhythm exists at the end of the experiment (Figs. 2,3). The specific intensity of this rhythm, as determined in functional tests of eye closure, increased by 16-22%. In addition to changes in the α-rhythm indexes, the EEG also revealed a tendency toward an increase in the activity of the low-frequency rhythms with an oscillation period of 2-7 Hz/sec.

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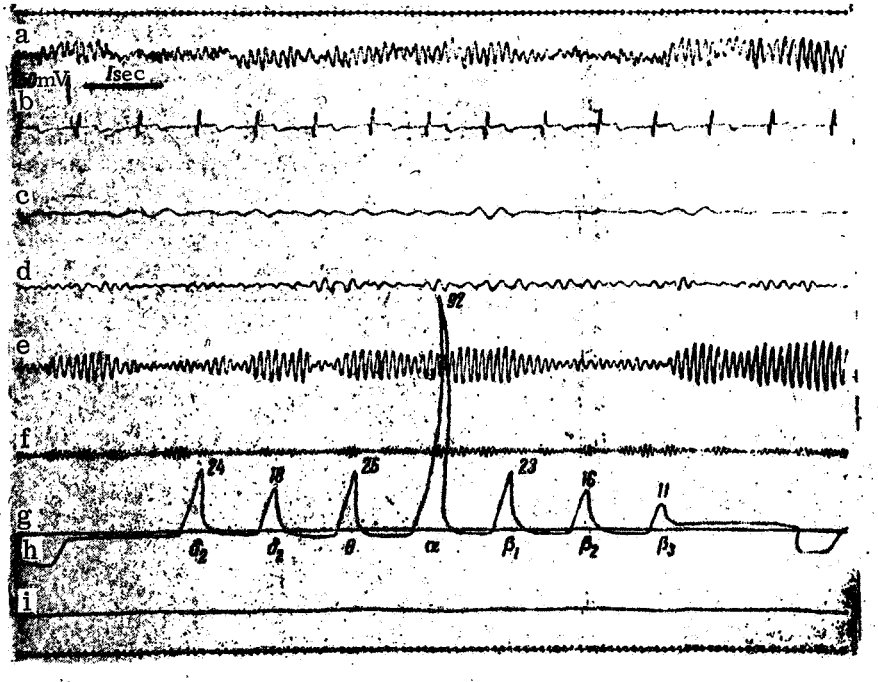

Figure 2. Sample of an EEG Record made of the Test Subject at the Beginning of the Experiment While Making a Functional Test of the Eye-Closing Operation:

a—EEG of the Forehead - Occiput, Left Side; b—EKG; c, d, e, f—Oscillation Frequencies of EEG Waves in the Range of 2-4 Hz Δ one rhythm), 5-7 Hz θ-rhythm), 8-13 Hz (α-rhythm), 14-20 Hz β-one rhythm), as Elicited by Filters of the Analyzer; g—Amplitudes of the EEG Frequencies from Integrator Indexes over 10 sec of Analysis; h—GSR; i—EMG.

Electromyographic studies made during the execution of the functional tests indicate that the bioelectric activity of the muscles decreased appreciably toward the end of the experiment. Thus, in making a functional test of rhythmic depression of the keys of an instrument, the bioelectric activity of the flexors of the right wrist decreased from 300 to 200 microvolts. In a number of cases partial and arhythmical oscillations were noted on the recorder EMG toward the end of the experiment.

In investigating the galvanic skin reactions (GSR) recorded while carrying out tests of the rapid transfer of attention it was observed that toward the end of the experiment the GSR amplitude dropped from 650 to 480 microvolts, i.e., by 26%.

Under the effect of the experimental conditions the test subject also showed a decrease in the functions of respiration and gas exchange. The rate of the respiratory cycles decreased from 14-13 to 10 per min during the morning hours. The greatest decrease in respiratory rate was observed on the 8th and 10th days. Toward the end of the experiment the respiratory rate increased toward the end of the experiment, reached the original values and, on the 13th day, after the cabin was unsealed, had exceeded the original values (Fig. 4). During the evening hours the respiration rate was in the range of 12-16 per min; in the second half of the experiment, a certain increase in fluctuation of the breathing rate was observed.

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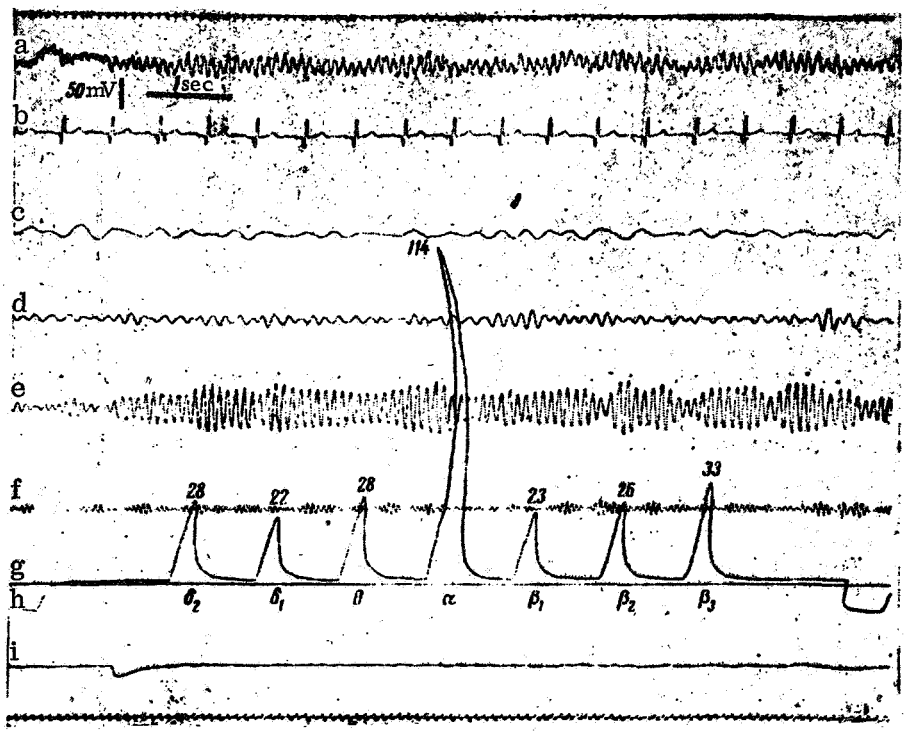

Figure 3. Sample of an EEG Record made of the Test Subject at the End of the Experiment Devoted to Testing Eye Closure.

Notation as in Fig. 2.

It should be noted that in addition to a decrease in the respiration rate of the test subject in the course of the experiment, the pulmonary ventilation also decreased by 360-1600 ml/min. The vital capacity of the lungs changed only slightly. The magnitude of the oxygen required dropped regularly from 256 to 176-240 ml/min. The dynamics of CO_2 evacuation from the human organism /165 was 199.7 ml/min. In the next three days it had dropped to 144-147 ml/min; subsequently the amount of evacuated CO_2 fluctuated within the limits 128-202 ml/min.

The magnitude of the basic exchange in the first few days of the experiment was 1,759.7 kcal, which was 118% the required magnitude; on the 3rd and 5th days it was 1,271.5 kcal (85.3%). In the second half of the experiment the magnitude of the basic exchange again rose, lying within the range 1,551-1,681 kcal (105-114%).

In the morning hours of the first half of the experiment the pulse rate was somewhat high, as compared with the initial values, lying in the range 68-74; on the 12th day it rose temporarily to 80 per min. During the evening hours throughout the experiment a tendency was observed toward a decrease in the pulse rate from 85 to 62 per min; only on the 13th day after the cabin was opened (but the test subject was still in his seat) did the pulse rate rise to 89 per min (Fig. 4).

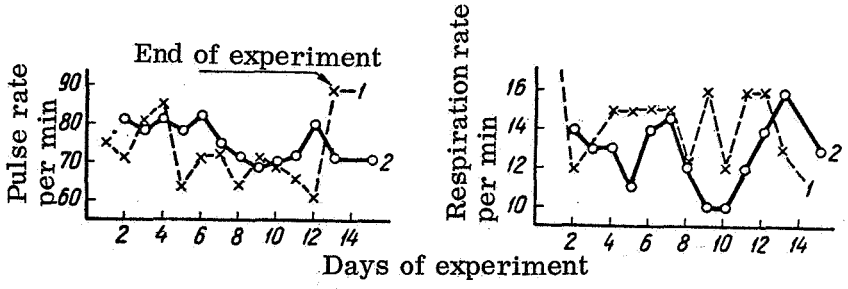

Figure 4. Dynamics of Pulse Rate and Respiration Rate of Tester on Different Days of Experiment; Evening (1) and Morning (2).

Of interest are the data on the change in pulse rate under a constant physical load while working with the wrist dynamograph. In the first half of the experiment the pulse rate during rhythmic work on the dynamograph was 115-120% of the original value, and 117-141% during the second half of the experiment. When the dynamograph was kept in the compressed state (static work), the pulse rate in the first half of the experiment increased to 112-118, and to 113-131% in the second half. When the breath was held during inspiration, the pulse rate also increased appreciably in the second half of the experiment.

Analysis of electroplethysmograms showed that the phase relations of the cardiac activity during the experiment did not exceed the mean values typical of healthy people. Only in the middle of the experiment was it possible to note /166 some reduction in the phase of the isometric tension. Obviously such a change is characteristic of a state of hypodynamia.

Analysis of the EKG records showed a decrease in the amplitude of the R and T spurs, an insignificant decrease in the segment ST and a certain retardation of the auriculoventral conductivity. It can be assumed that the decrease in amplitude of the R and T spurs was caused not only by a change in the biomechanism of the cardial muscle, but also by an increase of the interelectrode resistance.

With the aim of studying the hemodynamics before and after the experiment we recorded the tachooscillograms and arterial oscillograms of the test subject on a Savitsky mechanocardiograph. In a passive orthostatic check made during the first hour after the experiment, the arterial pressure of the test subject was noted to be considerably higher than in the initial state, and the volume of blood per stroke per minute was also noted to be sharply reduced. Before the experiment, the volumes per stroke per minute during the orthostatic check decreased from 89 (6.04 l/min) to 54 ml (511 l/min), while the arterial pressure increased from 112/65 to 127/78 mm Hg, but after the experiment the blood volume per stroke per minute decreased during the same functional check from 72 ml (5.13 l/min) to 44 ml (3.67 l/min), while the arterial pressure of the blood increased from 123/74 to 132/192 mm Hg (A. V. Beregovkin).

On the second day after the experiment a passive orthostatic check revealed no noticeable increase in the arterial pressure and no distinct decrease in blood volume per min, and on the third day there was almost complete recovery of the reaction of the cardiovascular system to the orthostatic check.

Deserving of attention are the data on the response of the test subject to functional tests in the form of applied loads and doses of physical work. These tests were performed both before and after the experiment under ordinary conditions.

The maximum residual stress after the experiment was almost unchanged (10.5 g's before and 10 g's after the experiment). The trend of the shifts in physiological reactions also was identical. No appreciable difference was noted in the change of respiration rate in both cases. The rate of heart contraction upon application of loads after the experiment was somewhat greater than in the initial state. The time required to normalize the pulse rate increased after the experiment to 4 min, while it was 1 min in the initial state. The responses time of motor reactions by the test subject to light signals increased considerably. Also noted were changes in the tonus of the minute veins and capillaries of the test subject. When extreme loads were applied, the amount and volume of hemorrhage into the integuments of the back, hips and buttocks of the test subject were considerably greater after the experiment than in the initial state (A. R. Kotovskaya). /167

Considerable shifts in the raction of the organism of the test subject were also observed when a 3-minute running test at the rate of 180 paces per min was completed after the experiment. Prior to the experiment, after a 3-minute run, the pulse rate increased from 74 to 152 beats/min, the breathing rate from 14 to 24 per min, and the systolic and diastolic pressures from 100/60 to 150/30 mm Hg. These physiological indexes recovered in 4 min. After the experiment, after the same exertion, the pulse rate increased from 74 to 172 beats/min, the breathing rate from 14 to 30-48 per min, and the arterial pressure from 108/58 to 170/20 mm Hg. The physiological indexes did not normalize in 5 min (A. V. Beregovkin).

During a test run with the dynamograph the test subject exhibited a post-experimental decrease in muscle strength of the right hand as well as an increase in the supplemental forces required to keep the dynamograph in the compressed state. No appreciable changes in the coordination of hand motion were observed from a coordinograph check on the 2nd and 3rd days after the experiment.

From the data of a large number of examinations no pathological changes whatever were detected in the organism of the test subject after the experiment. The periodic appearance of acetone bodies in the urine and also of an insignificant amount of sugar (0.2%) must obviously be considered as temporary functional dislocations. Also to be considered as temporary dislocations are variations in vascular reactions (plethysmograms), namely, a decrease in reaction to deep inspiration and cold, as well as the disappearance of reaction to oral counting and to brief delay in breathing.

As evident from the data, several changes were observed in the state and efficiency of the test subject, despite the fact that he estimated his state of health as completely satisfactory throughout the experiment. In view of the fact that the parameters of the microclimate in the spacecraft cabin did not change appreciably, and the food intake and water supply were normal, the above-mentioned variations in the reactions of the cardiovascular and respiratory systems and also of the overall status of the test subject are apparently related to the effect of prolonged hypodynamia and isolation. At the start of the experiment the effect of these factors was accompanied on the part of the test subject by an orientative reaction to the environment, which showed up as a persistent increase in the pulse rate, inaccuracy of motion in orienting the ship, midway in the experiment, the effect of these factors was accompanied by the development of adaptive-compensatory reactions, followed by an increase in general fatigue and disruptions in the state of a number of basic vital functions of the organism.

The presence of fatigue in the test subject showed up as a steady decrease in the quality of work in spacecraft orientation, deterioration of the motor skill in transmitting signals by teletype and a decrease in the capacity of the visual analyzer in choosing from tables of useful signals. The presence of fatigue and a decrease in the reactivity of the central nervous system are indicated by the galvanic skin reaction of the test subject to external stimulation and by a slowing down of the response reactions to light signals. At the same time the EEG revealed an increase in the index of low-frequency oscillations and exaltation of the α-rhythm. /168

The general fatigue of the test subject was apparently also reflected by a decrease in muscular strength of the wrists, inaccuracy of the muscular forces, decrease and high irregularity of the amplitudes of the electromyograms accompanied by the simultaneous appearance of high-amplitude splashed.

During the experiment and for three days after it was over the reaction of the cardiovascular system in response to a passive orthostatic check and to physical forces was observed to be more pronounced than in the initial state. This is apparently a reflection as much as general fatigue and a change in the central nervous system as of the direct effect of hypodynamia on the blood circulation [1, 2]. The interruption of vascular tonus was manifested very distinctly as an increase in the amount of subcutaneous hemorrhage when forces were applied after the experiment.

Data analogous to ours on the effect of prolonged isolation and hypodynamia when test subjects are placed in the usual and a variable gaseous medium had also been collected earlier by other researchers [3, 4, 9, 11, 14, 16]. They pointed out that under the effect of hypodynamia and restriction of afferent signaling psychic reactions are combined, negativism appears in the execution of operational tests, the efficiency is lowered, and the functions of breathing and blood circulation decrease. Kakurin et al. [6] noted that prolonged hypodynamia sharply decreases the capability of the test subjects to transmit information (up to 25%). Izosimov and Myasmikov [5] observed that isolation of test subjects resulted in a decrease in reactivity and excitability of the cortex of the brain and that low-frequency components appear in the EEG. The pronounced effect of hypodynamia on the overall status and efficiency of human beings was also noted in the work of L. V. Korobkov [7] and B. A. Lampusov [8].

The above-mentioned functional dislocations in a test subject under the effects of prolonged isolation and hypodynamia make it urgently necessary to further study of the effect of these factors on the human organism and to seek optimal working and breathing conditions for astronauts.

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